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Evaluating BMPs in a Claypan Watershed

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Abstract*.* *The United States Department of Agriculture Conservation Effects Assessment Project (CEAP) was initiated to quantify the benefits of conservation practices on a national scale. This paper will address water quality benefits from conservation practices implemented at the field level using measured water quality data from the Goodwater Creek watershed in the claypan area of north central Missouri. Eleven years of hydrologic and climatic data from 1993-2003 were analyzed to identify trends and possible effects of best management practices (BMPs), including grassed waterways and terraces, on atrazine stream loadings and concentrations. During this period, area implemented with BMPs increased by 12%. Trends were identified using regression models. Over the time period, atrazine levels have been affected by drier, warmer springs, and increased no-till practices causing earlier application of atrazine, increased levels of atrazine in April, and decreased levels as the season progressed. Atrazine loading was reduced significantly over the entire eleven* *year time period (P<0.10). Over the months of April, May, and June significant decreases were detected for atrazine concentrations (P<0.05). Data at this time does not attribute the reduction of atrazine to BMPs. SWAT modeling is planned to determine if the SWAT model is sensitive enough to produce data that follow the statistical trends found in this study and to determine what level of BMP implementation would be required to see greater decreases in atrazine.*

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Keywords. BMPs, CEAP, Claypan, Atrazine, Goodwater Creek

Introduction

The United States Department of Agriculture Conservation Effects Assessment Project (CEAP) was initiated to quantify the benefits of conservation practices on a national scale. Water quality benefits cannot be detected at that level. It is necessary to study smaller scales to gain prospective on the impacts of implemented practices. Goodwater creek watershed is on such scale. Goodwater Creek watershed was established in 1971 and became the principal field research site for the Missouri Management Systems Evaluation Area (MSEA) project in 1990. Analysis of data collected from Goodwater Creek watershed will be used to identify trends concerning the effect of best management practice (BMP) implementation on atrazine loadings and concentrations.

Goodwater Creek Watershed Description

The 7,250 ha Goodwater Creek watershed lies within the Central Claypan Soil Major Land Resource Area (MLRA 113) of Audrain and northeast Boone Counties (fig. 1), about 45 km north of Columbia, MO. Goodwater Creek is a tributary of Young's Creek, 14-digit hydrologic unit code (HUC) 07110006030001, itself divided into the Lower and Upper Young's Creek watersheds. Young's Creek is part of the Salt River system which drains to Mark Twain Reservoir. Mark Twain Reservoir serves recreational use and the public drinking water supply for approximately 42,000 people. The consistently high spring and summer time atrazine levels have been an on-going concern for Mark Twain Reservoir. The water quality issues in Goodwater Creek watershed are representative of those in the Salt River system: high pesticides, nutrients, and sediment loadings.

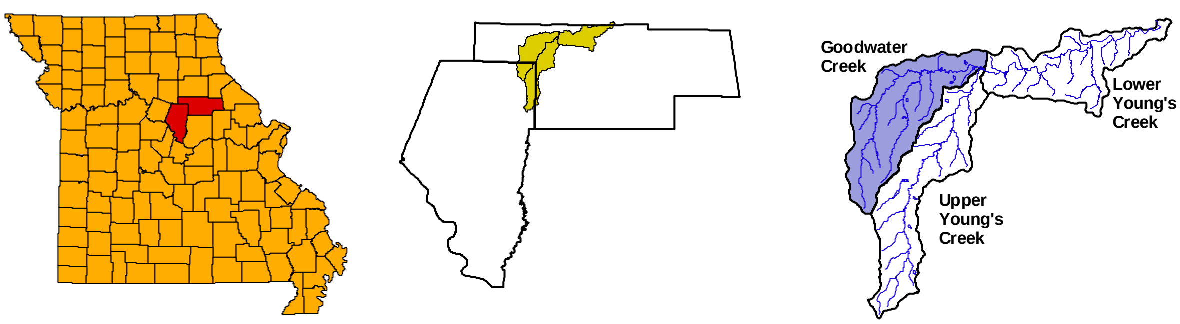

Figure 1. Location of the Goodwater Creek Watershed.

Topography of the watershed is nearly level, with most areas having 0-3% slopes, but the natural drainage system is well developed (fig. 2). The Goodwater Creek watershed includes part of Centralia, a small town (population 3,700) located at the southern end of the Goodwater Creek watershed. The remainder of the watershed is mostly agricultural with row crops (70% consisting of corn, wheat, soybeans, and sorghum), grassland (10%), and woodland (10%). Audrain and Boone counties receive about 1000 mm precipitation per year, 75% of it during March through October. The average temperature in winter is 0^{o}C and 22.5^{o}C in the summer.

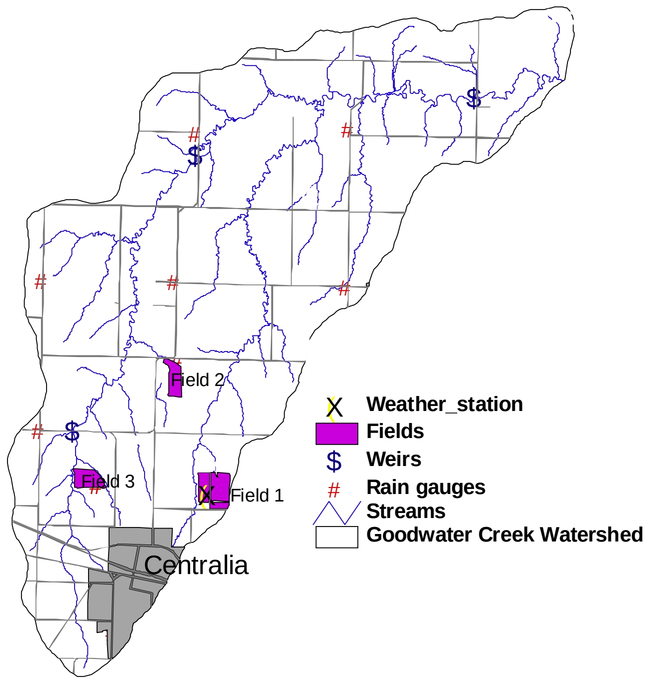

Figure 2. Research infrastructure of the Goodwater Creek watershed.

Soils

Soils within the basin were formed in Wisconsin and Illinoian loess overlying pre-Illinoian glacial till. Illuviation of the high clay content loess resulted in the formation of argillic horizons located 0.15 to 0.30 m below the soil surface containing 40-60% smectitic clays. The Adco-Putnam-Mexico soil association predominates in the flatter upland areas, and these soils tend to be less eroded and have greater depths to the claypan than the terrace areas. The Mexico-Leonard soil associations occur in more sloping terrace and alluvial areas where the depth to claypan is often <15 cm on side slopes because of erosion. The claypan is not present within alluvial areas immediately adjacent to streams. The naturally formed claypan represents the key hydrologic feature of the basin, and it is the direct cause of the high runoff potential of these soils. Most soils within the basin are classified in the hydrologic group C or D by NRCS.

Claypan soils are characterized by the presence of a subsoil horizon with an abrupt and large increase in clay content compared to the overlying materials occurring within a short vertical distance in the soil profile (Soil Survey Staff, 1992; Soil Science Society of America, 1997). In the Midwestern U.S., the high-clay subsoil horizon in these soils occurs at depths varying from 13 to 46 cm with clay content ranging from 350 to 600 g/kg (Soil Conservation Service, 1981; Miles and Hammer, 1989; Natural Resources Conservation Service, 2001; Blanco-Canqui et al., 2002). The Midwestern U.S. claypan region encompasses an area of about 4 million ha within Missouri, Illinois, and Kansas (Anderson et al., 1990). The relatively low saturated hydraulic conductivity of the claypan perches water in the surface horizon creating a high probability of runoff in most years during the winter and spring periods (Blanco-Canqui et al., 2002). Due to the high shrink-swell potential of the smectitic clays present in these soils, there is also a high probability of annual shrinkage cracks forming in these soils during the late summer and early fall periods which enhances the recharge of shallow aquifers during the fall and early winter periods each year (Baer and Anderson, 1997).

Atrazine

Atrazine is an s-triazine-ring herbicide that is used to stop pre and post emergence broadleaf and grassy weeds in major crops such as corn and sorghum. Atrazine has a solubility of 32 mg L^{-1} causing it to be susceptible to water transport. Of atrazine removed from fields, 75 to 100% is in water phase; leaving 25% or less to be removed through sediment loses (Wauchope, 1978). The half-life of atrazine can range greatly depending on environmental conditions. In water the average half-life is 32 days, but under anaerobic conditions, degradation could take as long as 159 days (Orme and Kegley, 2006).

Conventional atrazine management consists of one application of 2.25 kg/ha during or shortly after planting corn at the end of April or beginning of May. In a no-till system, atrazine would be applied at 1.12 kg/ha about one month before planting to kill weeds. A second application follows no-till planting (1 to 2 weeks after) at 1.25 kg/ha. No-till planting is typically two to three weeks later than conventional corn planting, possibly less during dry and warm planting seasons. Education efforts through the MSEA project in Goodwater Creek encouraged farmers to apply less atrazine after planting (1.25 instead of 2.25 kg/ha) and follow with a second application later in June, if necessary. The second application could be atrazine or another herbicide.

Methods

Instrumentation and Data Collection

Complete documentation including and beyond what is in this paper for Goodwater Creek watershed has been collected and summarized by Sadler et al. (2006). Goodwater Creek watershed had been instrumented with a broad-crested v-notch concrete runoff weir in 1971 (weir-1). Surface water quality has been evaluated from analyses of weekly grab samples collected at the weir and from analyses of automated samples collected with a flow-proportional automated sampler installed at the weir (fig. 2). Streamflow was measured continually using an ISCO 3230 bubbler level sensing monitor. Automated water samples were taken with an ISCO 3700FR. The automated sampler is programmed to take samples throughout rain events and is activated to sense for events when stage exceeds 0.15 m stage height (the threshold of flow over the weir).

Streamflow and rainfall within the watershed have been monitored continually from 1971 to present and water quality near the outlet of Goodwater Creek has been monitored since fall of 1991. All water samples were analyzed for concentrations of sediment, nutrients (NO_3-N, NH_4-N, and PO_4-P), and herbicides (acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, and metribuzin). Some herbicides were not analyzed for this entire period of record, but all herbicides listed above have been analyzed for a minimum of nine years. Streamflow discharge from the weir was separated into base flow, which accounts for about 15 percent, and surface runoff, which accounts for about 85 percent of total streamflow, by analysis of runoff hydrographs. Mean annual streamflow (surface runoff plus base flow) is 292 mm in Goodwater Creek watershed, which is about 30 percent of mean annual precipitation.

An automated weather station is located in the southeast portion of the watershed (fig. 2) at a MSEA established research field. Precipitation events were also measured throughout the watershed using recording rain gauges. There are 18 variables associated with the climatic database, including precipitation, wind speed and direction, solar radiation, temperature, and humidity. Observations for most of the climatic variables are recorded on a mean hourly or daily basis and stored in a climatic database.

Management Practices

The primary goal of this study is to determine whether BMPs implemented within Goodwater Creek have had a quantifiable impact on water quality. In order to do this, a record of BMPs implemented within the watershed was established. Location, type, and area protected by BMPs that were established in 1990 or later was provided by NRCS offices from Boone and Audrain counties. The main BMPs in the watershed include vegetative waterways and terraces (with and without underground outlets). Other minor BMPs in the watershed consist of conservation reserve program (CRP), vegetative filter strips, vegetative buffers, water diversions, lagoons, and prescribed grazing. From 1990 through 1993, 361 ha of the watershed area (5%) had BMPs installed. By 2003, that amount increased to 1,212 ha (17%) (Table 1).

Table 1. Increase in BMP Protected Area from 1993-2003

BMP	Area (ha) protected by:		Increase
	1993	2003	
Vegetative waterways	105	410	290%
Terraces (all kinds)	224	600	168%
Other BMPs	32	202	531%
Total	361	1,212	236%

Through the MSEA project, educational efforts were made to promote conservation tillage and no-till practices and better equipment was made available through the Soil and Water Conservation District (SWCD). These two factors resulted in a large increase in conservation and no-till implementation in the 1990's. Data collected for Audrain County shows that most of the change in tillage practice occurred from 1992 to 1994. Implementation has remained stable with about 70 to 80% of cropped land in Audrain County in conservation and no-till practices from 1995 to 1998 (fig. 3) (CTIC, 2006).

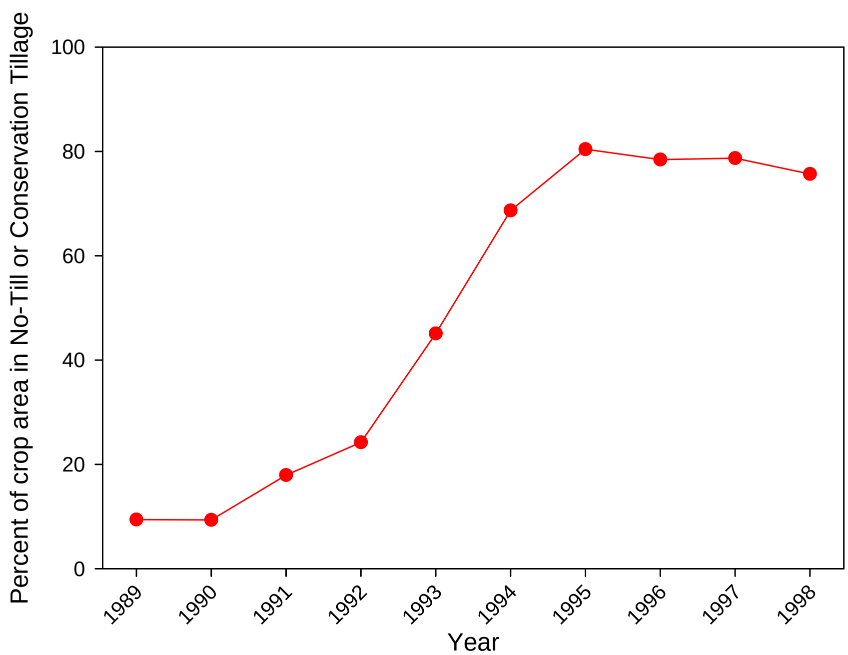

Figure 3. Percent of Audrain County crop area in no-till and conservation till.

This paper will primarily deal with the herbicide atrazine since it is a common pesticide used in the Goodwater Creek watershed and the data available extends from 1993 to 2003. Atrazine samples were collected and analyzed by the USDA-ARS Cropping Systems and Water Quality Research unit in Columbia, MO (Lerch et al., 1995, 2003). Climatic, flow, and atrazine data were compiled on a daily time step. Atrazine concentrations were recorded during rain events and in weekly grab samples; therefore, data for atrazine only exists on days when samples were taken. This accounts for 835 days of the record. Daily loadings were derived from the atrazine concentration data and stream flow.

Both the concentration and loading of atrazine were will be evaluated for trends. Data were examined with SAS using the Regression (REG) and General Linear Model (GLM) procedures. Different time periods were studied to see distinction in trends on a monthly, seasonal, and yearly timescale.

Results and Discussion

Corn planting progress records for the NE region of Missouri were used to estimate relative planting dates (G. Danekas personal communication, June 2004). Atrazine application data obtained from the National Agricultural Statistics Service (NASS) database for Missouri indicate a nearly constant area to which atrazine was applied in Missouri (P=0.411), usually between 80 and 90% of corn (fig. 4, USDA 2005). Data was not available at the county level. There has been an overall increase in the amount of atrazine applied in Missouri (P=0.010) (fig. 4). Much of the increase in total atrazine applied may be due to increased corn production in Missouri. This trend will need to be confirmed with additional data. Data for atrazine application on sorghum was only available for 2003 with 94% of sorghum treated with atrazine and a total application of 132,000 kg.

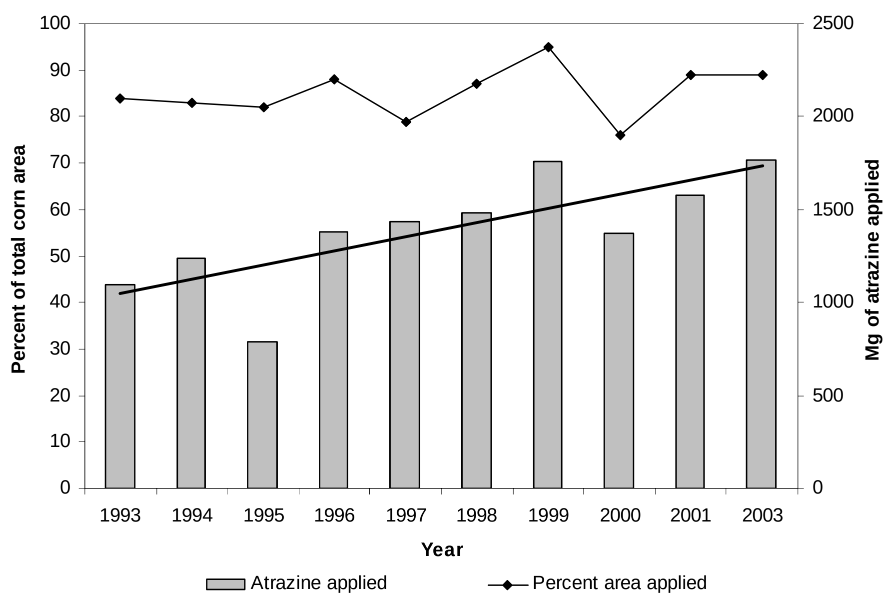

Figure 4. Percent area treated with atrazine and total amount applied to corn in Missouri.

Weather and Runoff

Weather and runoff data were analyzed for possible trends using the REG procedure to better understand influencing factors that might affect atrazine concentration and loading. No significant change in precipitation was found for the eleven year time period (P=0.394). To some extent, there was a decreasing trend in precipitation for April across all years (P=0.117) (Table 2). This reflects a drier spring season starting about 2000. A look at the planting progress records shows that producers took advantage of dry spring weather and completed their planting earlier in the season. Changes in precipitation for May and June were not significant (P=0.426 and P=0.694, respectively). A drier April also had less runoff (P=0.134). Although the relationship is not highly significant, it is expected with less rainfall. The total time period had a similar decrease in runoff (P=0.132) but there was no decrease in precipitation. Observation of the maximum and minimum daily temperatures over time show definite increases for the watershed. Both maximum and minimum temperature increased over the entire time period (P=0.003 and P=0.108, respectively) and particularly for April (P=0.0004 and P=0.0008, respectively, Table 2). The increase in temperatures may suggest earlier vegetative growth. This is especially important for vegetative BMPs that may have been more effective earlier in the year than previously.

Table 2. Average Daily Maximum Temperature and Precipitation for April, May, and June

	Average Daily					
	Maximum Temperature (^{0}C)			Precipitation (mm)		
Year	April	May	June	April	May	June
1993	15.69	22.73	27.88	5.43	2.95	4.94
1994	18.11	22.87	29.36	8.84	1.07	2.95
1995	16.90	19.86	27.27	4.35	8.94	4.28
1996	17.11	23.08	27.62	2.19	5.59	2.56
1997	14.89	20.76	26.50	2.77	3.96	3.16
1998	16.81	26.07	27.57	2.81	2.21	7.59
1999	18.42	23.11	27.75	6.12	2.91	6.11
2000	19.06	25.50	26.16	0.79	2.93	5.41
2001	21.87	23.29	27.02	3.67	5.60	5.10
2002	19.24	21.52	29.42	4.53	7.52	1.72
2003	18.80	22.05	26.05	3.32	4.15	5.37

Atrazine Concentration Trends

Figure 5 shows the atrazine concentrations as they vary by season. The highest concentrations are in the months of April, May, and June with diminishing concentrations through the rest of the year. A statistical regression of all months also showed that April, May, and June were the peak months for atrazine concentration and loading. This is corroborated by planting progress records obtained for the NE region of Missouri (G. Danekas personal communication, June 2004). Over the 11 year period, 99 days were sampled for atrazine in April, 104 in May, and 84 in June. Regressions were calculated for individual months of April, May, and June for all years; the combined period of April, May, and June for all years; and all twelve months for all years.

The three month period taken together yields a decrease in concentration records (P=0.073); however, a decrease in concentration for all twelve months of the time period has not been detected (fig. 6). Concentrations significantly increased (P=0.016) for April over time (fig. 7). In May, there was no significant change in atrazine concentration (P=0.957), and in June there was a significant decrease (P<0.0001) (fig. 7). The trends in concentration over time are largely attributed to earlier planting and atrazine application by producers to kill weeds in no-till systems. The earlier application of atrazine allows the chemical more time to degrade, leaving less to be detected in June. The drier years may have led to the overall decrease in atrazine for the three month period by allowing the product to stay in the field and degrade, causing less availability for wash off over time.

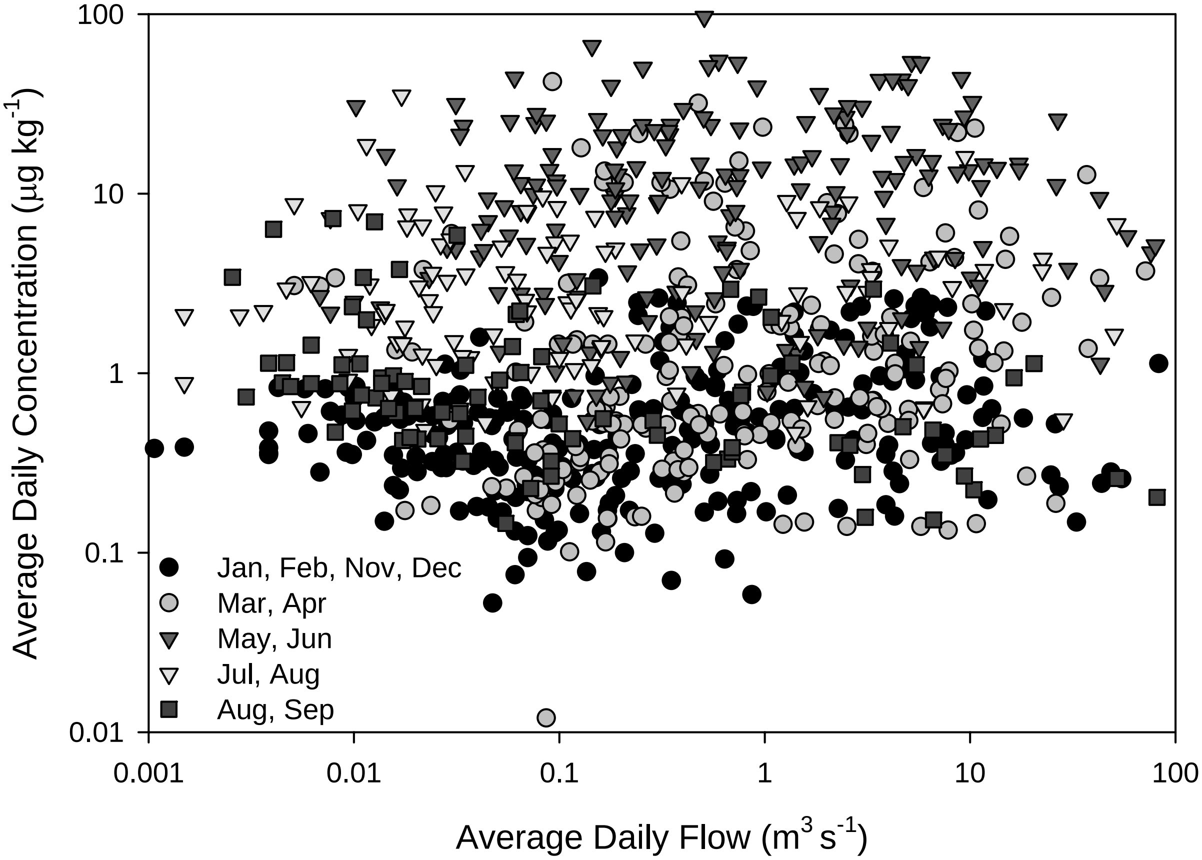

Figure 5. Average daily flow versus atrazine concentration for all years, by season.

Atrazine Loading Trends

Unlike concentration, there is a general decrease in atrazine loading detected when examining the twelve months of the entire time period (P=0.073) (fig. 6). When combining April, May, and June together the decrease is even more significant (P=0.042) (fig. 6). The individual months of April, May, and June all showed some decrease in loading, but there was no significance to the decrease (P=0.134, P=0.506, and P=0.161, respectively) (fig. 7). Even though there is no significant decrease for individual months, the significant decrease for the combined three months suggests that an increased number of observations was necessary to detect the trend. Increased degradation in the field may have contributed to decrease of load over time. The decrease in runoff could have also played a part if there was insufficient runoff from an event to wash the atrazine into the stream.

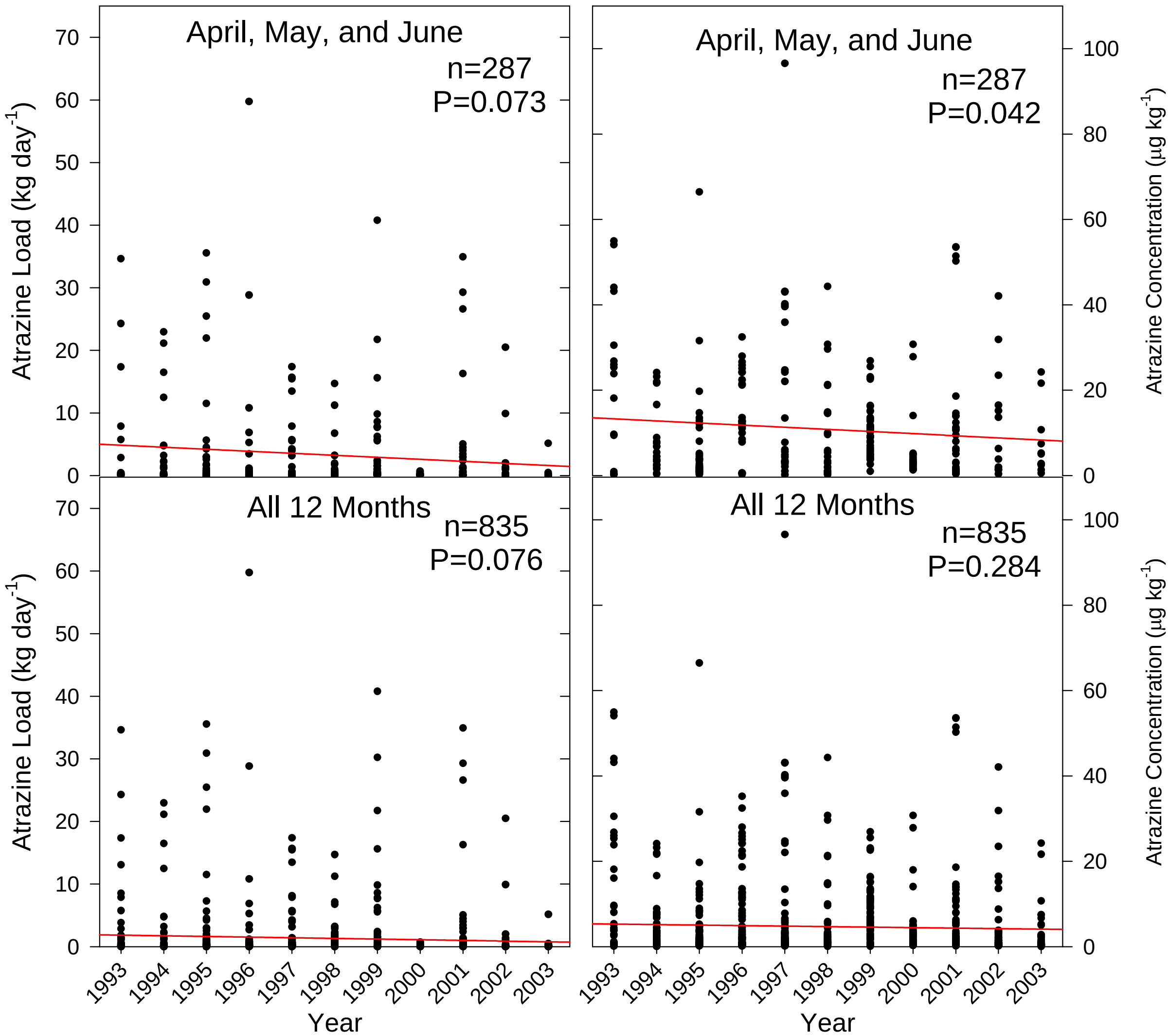

Figure 6. Plots of atrazine loading and concentration for April, May, and June; and all 12 months with regressions.

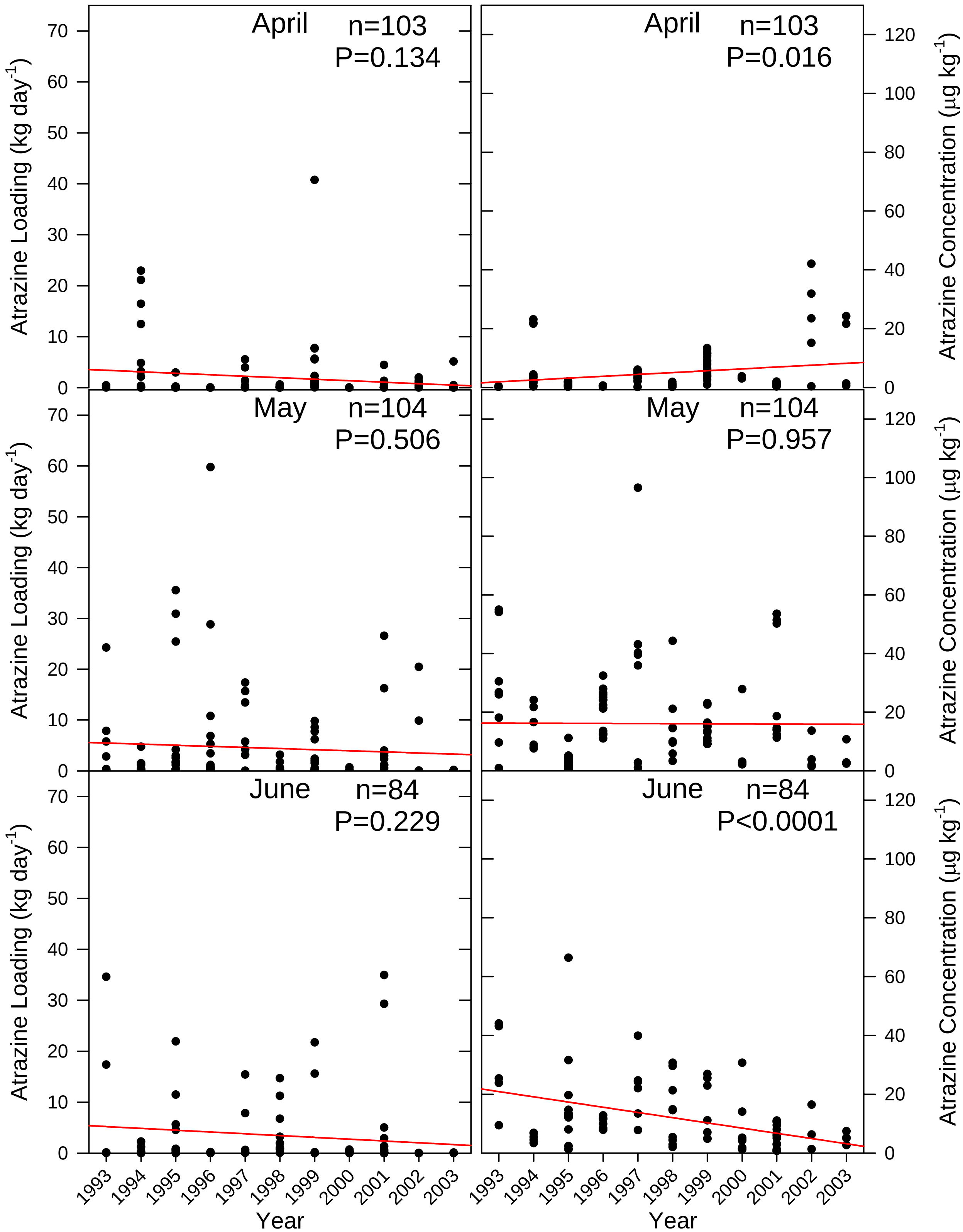

Figure 7. Atrazine loading and concentration charts for the individual months of April, May, and June with regressions.

Effect of BMPs

An additional variable was created to further examine the effect of BMPs on atrazine in Goodwater Creek. The variable, represented the percent of land protected by BMPs in the watershed using the BMP record created by Boone and Audrain Counties' NRCS offices. This variable did not account for tillage practices. Best management practice installment was provided on a yearly basis and the percentage of area incorporated into BMPs was considered constant during each year. Earlier results showed atrazine to be significant with year. The GLM procedure was used to fix the effect of year when investigating if additional trends could be detected through the amount of BMP implementation.

Only May and April showed significant trends after fixing year. April showed an increase in concentration with increasing BMP implementation ($P<0.0001$). This increase suggests that atrazine concentration increased at a rate faster than the implementation of BMPs. The reasons for the increase in atrazine concentration in April have already been discussed. May showed a decrease in concentration with increasing BMP implementation ($P=0.007$). There was no relationship between year and concentration in May ($R^2=0.0000$). This indicates the level of BMP implementation is a better predictor of May atrazine concentration than time. This decrease could be showing that increased implementation of BMPs within the watershed may have had a positive effect on atrazine concentrations, but other interacting factors, such as weather, may be masking decreases in atrazine concentrations.

Conclusions

In the time period analyzed, both loading and concentration of atrazine have been affected by drier, warmer springs allowing earlier planting and increased no till practices requiring early weed eradication. Both factors contributed to earlier applications of atrazine. This caused an increase in the levels of atrazine detected in April and decreased levels as the season progressed due to transport and/or degradation. Increased education may have also helped to reduce total loading over time by encouraging producers to use less atrazine per application. Data at this time is not conclusive that atrazine levels have been reduced through BMP implementation. Atrazine transport and degradation are largely dominated by weather and management and it may be necessary to have a much greater amount of land in BMPs before a reduction can be attributed to them.

Future Research

Further research is planned for other water quality analytes (sediment and nutrient) sampled in Goodwater Creek that may be more sensitive to BMPs. Trends will be identified for the loadings and concentrations of those analytes. SWAT modeling is planned to determine if the model is sensitive enough to predict concentrations and loading values that follow the statistical trends found in this study and in future analyte studies. It will then be utilized to determine what level of BMP implementation would be required to see decreases in atrazine.

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References

Anderson, S.H., C.J. Gantzer, and J.R. Brown. 1990. Soil physical properties after 100 years of continuous cultivation. *J. Soil Water Conserv.* 45:117-121.

Baer, J.U., and S.H. Anderson. 1997. Landscape effects on desiccation cracking in an Aqualf. *Soil Sci. Soc. of Am. J.* 61:1497-1502.

Blanco-Canqui, H., C.J. Gantzer, S.H. Anderson, E.E. Alberts, and F. Ghidey. 2002. Saturated hydraulic conductivity and its impact on simulated runoff for claypan soils. *Soil Sci. Soc. Am. J.* 66:1596-1602.

Conservation Technology Information Center, 2004. National crop residue management survey, available on line at: www.ctic.purdue.edu/CTIC/CTIC.html, accessed July 2006.

Lerch, R.N. and P.E. Blanchard. 2003. Watershed vulnerability to herbicide transport in northern Missouri and southern Iowa streams. *Environ. Sci. Technol. 37*, 5518-5527.

Lerch, R.N., W.W. Donald, Y-X. Li, and E.E. Alberts. 1995. Hydroxylated atrazine degradation products in a small Missouri stream. *Environ. Sci. Technol. 29*, 2759-2768.

Miles, R.J., and R.D. Hammer. 1989. One hundred years of Sanborn field: soil baseline data. p.100-108. *In* J.R. Brown (ed.) Proc. Sanborn Field Centennial, Pub. No. SR-415. Univ. of Missouri, Columbia, MO.

Natural Resources Conservation Service. 2001. Soil survey of Boone County, Missouri. U.S. Dept. of Ag., US Gov. Printing Office, Washington, DC.

Orme, S. and S. Kegley. 2006. PAN Pesticide Database, Pesticide Action Network. San Francisco, CA. Available at: www.pesticideinfo.org. Accessed June 2006.

Sadler, E.J., R.N. Lerch, E.E. Alberts, and T.L. Oster. 2006. Long-Term Hydrologic Database: Goodwater Creek, Missouri. In *Proc 2nd Interagency Conference on Research in the Watersheds*. Coweeta Hydrologic Laboratory, Otto, North Carolina, 16-18 May, 2006.

SAS. 2002. *SAS User's Guide: Statistics*. Ver. 9.1. Cary, N.C.: SAS Institute, Inc.

Soil Conservation Service. 1981. Land resources regions and major land resource areas of the United State. Agric. Hdbk. 296. U.S. Dept. of Agric., U.S. Government Printing Office, Washington, DC.

Soil Science Society of America. 1997. Glossary of soil science terms, 1996. Soil Sci. Soc. Am., Madison, WI.

Soil Survey Staff. 1992. Keys to soil taxonomy. SMSS Technical Monograph No. 19, 5th ed. Pocahontas Press, Blacksburg, VA.

USDA. 2005. Agricultural Chemical Use Database: 1993-2003. National Agricultural Statistics Database. Washington, D.C.: USDA National Agricultural Statistics Service. Available at: www.pestmanagement.info/nass/. Accessed May 2006.

Wauchope, R.D. 1978. The pesticide content of surface water draining from agricultural fields—A review. J. Environ. Qual. 7(4):459-472.